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SOME DEDUCTIONS FROM A MEASUREMENT OF THE
HYDROGEN ION DISTRIBUTION IN THE HIGH ATMOSPHERE

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CAPTION

Figure 1 Theoretical Distributions of H^+ .

Reaction (1) and its reverse were taken as the source and loss processes for protons. Hydrogen and atomic oxygen were assumed to be distributed according to the hydrostatic equation; their concentrations at 500 km being taken as $7 \times 10^4 \text{ cm}^{-3}$ and $2.7 \times 10^7 \text{ cm}^{-3}$ respectively. Only Coulomb diffusion was considered. The numbers on the curves indicate the rate coefficient of reaction (1) in units of $10^{-10} \text{ cm}^3 \text{ sec}^{-1}$. The upward flux of protons at 900 km, corresponding to a rate coefficient of $3.9 \times 10^{-10} \text{ cm}^3 \text{ sec}^{-1}$, is $1.3 \times 10^7 \text{ protons cm}^{-2} \text{ sec}^{-1}$. The oxygen ion distribution and the proton concentrations (indicated by circles) obtained by Taylor et al (1963) are also shown.

Letter to the Editor: Journal of Geophysical Review

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The recent measurements of the ion composition above the F_2 peak by Taylor, Brace, Brinton, and Smith (1963) place some constraints on the magnitudes of two parameters of interest in the high atmosphere.

First, it is very probable that the charge exchange reaction



proceeds rapidly enough (Rapp, 1963) to establish a chemical equilibrium distribution of these species in the 300 km to 500 km region (Hanson and Ortenburger, 1961; Bates and Patterson, 1961). If this is so, then the atomic hydrogen concentration can be expressed as

$$n(H) = \frac{8}{9} \frac{n(H^+) n(O)}{n(O^+)} \quad (2)$$

where $n(X)$ represents the concentrations of species X . The concentration of atomic oxygen at 500 km derived from satellite drag data (A. Anderson, private communication) for the time of this experiment was approximately $2.7 \times 10^7 \text{ cm}^{-3}$. Using this value for $n(O)$, and the ion concentrations given by Taylor et al (1963), the atomic hydrogen concentration at 500 km is calculated to be $7 \times 10^4 \text{ cm}^{-3}$.

On the other hand, the values of $n(H)$ at 500 km predicted by Kockarts and Nicolet (1962) are $6.5 \times 10^3 \text{ cm}^{-3}$, $1.1 \times 10^4 \text{ cm}^{-3}$, and $1.9 \times 10^4 \text{ cm}^{-3}$

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for temperatures of 1273°K, 1155°K, and 1059°K respectively. The temperature derived by Taylor et al (1963) from the slope of the oxygen ion distribution curve, assuming plasma thermal-equilibrium, was $1235^{\circ} \pm 40^{\circ}\text{K}$, which is probably an upper limit for the atmospheric temperature since the ions and electrons are probably not colder than the neutral gas. The measurements of $n(\text{O}^+)$ are quite reasonable and reliable, and the $n(\text{O})$ value used is unlikely to be incorrect by more than a factor of two; thus it would appear that either the experimental value for $n(\text{H}^+)$ is too large, or that Kockarts and Nicolet (1962) have chosen too small a value for the source of atmospheric hydrogen.

Second, the rate coefficient K_1 for reaction (1) can be derived from a good $n(\text{H}^+)$ profile. The greater the rate coefficient, the higher the chemical equilibrium region will extend. If the hydrogen distribution were in diffusive equilibrium, it would be impossible to tell whether reaction (1) or diffusion controls the hydrogen distribution at a given altitude. If a quasi steady-state obtains, however, with a flux of protons into or out of the magnetosphere, a distinction can be made (Hanson and Ortenburger, 1961; Hanson and Patterson, 1963). Using the equations (their equations (28), (29) and (30)) and method of Hanson and Patterson (1963), attempts were made to fit the measured hydrogen ion profile using K_1 and the flux of hydrogen ions as adjustable parameters. The results are shown in Figure 1, together with the measurements of Taylor et al (1963). The effects of the He^+ ions have been neglected. It can be seen from Figure 1 that a rate constant of $K_1 = 3.9 \times 10^{-10} \text{ cm}^3 \text{ sec}^{-1}$ fits the measured data reasonably well, with an upward flux of $1.3 \times 10^7 \text{ protons cm}^{-2} \text{ sec}^{-1}$ at 900 km. This value for the rate constant corresponds to a reaction cross-section of $7.6 \times 10^{-16} \text{ cm}^2$.

The calculated upward proton flux is small compared to the normal downward flux of oxygen ions through the F_2 peak; this fact enhances the

position of Hanson and Patterson (1963) that the fluxes of protons between hemispheres are unlikely to affect the ionization level at the F_2 peak during the daytime.

The experimental values of Taylor et al (1963) for the proton (and helium ion) concentrations were obtained rather arbitrarily from the mass-spectrometer current measurements, in that the effects of vehicle velocity, angle of attack, possible changes in the ion sheath dimensions with ion concentration, and the electric drawing-in field were all lumped together into one constant. This procedure may distort both the magnitude and the shape of the derived light ion distributions. Hence, the value for K_1 is probably not as well determined as might be inferred from inspection of Figure 1, but is unlikely to be wrong by more than a factor of three.

It should be noted that; (a) the deduced value for the rate coefficient is influenced primarily by the shape of the proton distribution curve, and (b) the deduced atomic hydrogen concentration is influenced by the magnitude of $n(H^+)$ in the lower altitude region but not by the shape of the proton distribution curve.

It follows from (a) that vertical measurements of the ion distributions, made by means of sounding rockets, are necessary to obtain information about the interaction of the various dynamic processes affecting the ion distributions in the lower altitude transition region.

A direct mass-spectrometer measurement of the neutral atomic hydrogen concentration is difficult because of contamination problems. It would therefore appear from (b), that satellite measurements of $n(H^+)$ in the 400 km to 500 km region, with the aid of equation (2), provide a good means of obtaining the global distribution of $n(H)$.

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